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The emergence of the solar photovoltaic power industry in China

Zhen-yu Zhao [a,*], Shuang-Ying Zhang [b], Bryan Hubbard [c], Xue Yao [d]

[a] Department of Engineering Management, North China Electric Power University, Beijing 102206, China
[b] Economic Research Institute, Liaoning Electric Power Company Limited, Shenyang 110016, Liaoning, China
[c] College of Technology, Purdue University West Lafayette, IN 47907-2021, USA
[d] Beijing Association for Electric Power Industry, Beijing 100055, China

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ABSTRACT

Solar photovoltaic (PV) power is a new and green energy source. China has significant opportunities for solar energy utilization with its huge solar resource. The solar PV power in China has developed for 50 years, and experienced a rapid progress in the last 10 years. To address the needs of the fast growth of the PV power industry in China, it is critical to identify, analyze and understand the growth path and the characteristics of the industry. This paper summarizes the status of the solar energy resources and the development of the solar PV power industry in China, and puts forward the main factors that impacted the development of the industry. A study refers to the selected five main factors the factors are: technology research and development, industrial plans, laws and regulations, electricity price policies, and projects incentive policies. A multifaceted approach including literature survey, statistical data investigation, law review, and regulation and policy study are adopted to investigate these factors. Analysis of the typical events, the growth process and the characteristics of the five factors, allows the establishment of growth route models. The results can be a useful reference for the development of solar PV power industry in China and other countries.

Contents

1. Introduction

With the rapid development in the last 30 years, China's energy demand has grown at a rapid pace. Since 1978, China's average annual gross domestic product (GDP) growth rate has reached 10% and the growth in the annual average energy consumption has reached 5.2% [1]. With the current trend in energy consumption, China's primary energy demand will reach 4.8 billion tons of standard coal by 2020; the traditional energy resources can only meet 70% of this demand. In this framework of increasing demand and limited traditional resources, it is imperative to accelerate the development of renewable energy [2]. China has rich renewable

* Corresponding author. Tel.: +86 10 51963894; fax: +86 10 80796904.
E-mail address: zhaozhenyuxm@263.net (Z.-y. Zhao).

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energy resources and a huge development potential. According to projections, by 2050, China's capacity for renewable energy is projected to be equivalent to the total primary energy consumption in 2000 [3], which was 1.3 billion tons of standard coal. It is expected that solar energy will become an important new energy source for renewable energy in China in the future.

China has four types of renewable energies for commercial production of electricity, those include hydroelectric, wind, biomass and solar. Solar power has the greatest potential of these four sources [4]. Solar energy is a clean and renewable energy, and compared with traditional energy sources, it is renewable, safe, reliable, quite, and does not produce any pollution emissions. Due to the lack of emissions, the replacement of traditional energy sources with solar power can effectively reduce the "greenhouse effect". Currently solar photovoltaic (PV) power generation is the strongest technology for solar energy applications. China's solar PV power generation started in the 1960s, and after a long-term development, the solar PV industry has made tremendous progress and is rapidly growing, with dramatic progress in the last 10 years. Currently, it is necessary to identify the elements that impact the industry, to analyze the development characteristics of the industry, and to review the growth path of the industry. This paper reviews the growth routes of the PV power industry from five aspects, including the technology research and development, the industrial plans, the laws and regulations, the electricity price policies, and the project incentive policies.

This study is based on a comprehensive literature review as follows:

(1) *Literature survey*: an extensive literature survey was carried out to review relevant research papers. The survey covered the existing studies investigating the situation of Chinese PV power industry.
(2) *Statistical data investigation*: the statistical data adopted in this study are primarily retrieved from the State Council of China, the National Development and Reform Commission (NDRC), the National Bureau of Statistics of China, and the Ministry of Finance.
(3) *Regulation and policy studies*: the policy documents reviewed in this study include various official regulations and reports published by major authorities such as the State Council of China, the National Development and Reform Commission (NDRC), the Ministry of Finance, the Ministry of Housing and Urban–Rural Development, the Ministry of Science and Technology, and the National Energy Board.
(4) *Law review*: the laws reviewed include the renewable energy law and its amendment, and the energy conservation law and its amendment.

The results from the reviews and analysis of the various literature help to identify the evolution and milestones of the PV power industry in China. The results not only provide a panorama of the development history of the solar PV industry, but may also help to predict the future trends of the industry in China. Moreover, other countries around the world can benefit from this study to develop their own solar power industry.

2. Overview of the solar resources and solar PV power industry in China

2.1. Solar resources in China

According to the China Meteorological Administration, China has abundant solar energy resources. The total potential for solar radiant energy of 1.7×10^{12} tce (tons of standard coal equivalent) per year for the entire country. More than two-third of the country has over 2000 h of sunshine each year, which provides an equivalent annual solar radiation of over 5.02×10^{6} kJ/m^2 [5,6]. China's solar energy resource distribution is shown in Table 1. This illustrates the amount of solar radiation available. Compared with other countries in similar latitude, the solar radiant energy in China is superior to those in Europe and Japan, and similar to those in the United States. As can be seen in Table 1, provinces located in different latitudes and longitudes have different levels of solar irradiations. The country can be divided into five different regions from I to V [7]. The distribution of China's solar energy resources in different areas varies significantly; in general, the solar resources in the western region (such as Ningxia, Gansu, Xinjiang, Qinghai, and Tibet) are higher than that in the eastern region (such as Guangdong, Shaanxi, Anhui, Heilongjiang, Zhejiang, Fujian, Hunan, and Hubei), and the resources in the northern region (such as Hebei, Shanxi, Inner Mongolia, Shandong, Hena, Jilin, Liaoning, and Shaanxi) are higher than in the southern region (such as Sichuan, Guizhou, Chongqing, Guangxi, and Jiangxi). This does not, however, correlate with the demand for energy. China's electricity loads are concentrated in the eastern and the southern regions, unfortunately, the solar resource-rich regions in the Qinghai-Tibet Plateau, North China and Northwest China are far from the regions which consume the greatest electrical power load.

2.2. Solar PV power industry in China

Since the 1990s, China's PV power is developing rapidly and the installed capacity is increasing constantly. Fig. 1 shows the annual installed capacity and the cumulative installed capacity from 1976 to 2009 [8,9]. Based on current trends, the cumulative

Table 1
Solar energy resources in different regions of China.

Type	Annual sunshine hours (h/a)	Total annual solar radiation (MJ/m^2 a)	Total annual solar energy per m^2 expressed in units of energy produced by kg of standard coal (kg)	Provinces
I	3200–3300	6680–8400	225–285	Northern Ningxia, Northern Gansu, Southeastern Xinjiang, Western Qinghai, and Western Tibet
II	3000–3200	5852–6680	200–225	Northwestern Hebei, Northern Shanxi, Southern Inner Mongolia, Southern Ningxia, Central Gansu, Eastern Qinghai, Southeastern Tibet, and Southern Xinjiang
III	2200–3000	5016–5852	170–200	Southeastern Shandong, Southeastern Henan, Northwestern Hebei, Southern Shanxi, Northern Xinjiang, Jilin, Liaoning, Yunnan, Northern Shaanxi, Southeastern Gansu, Southern Guangdong, Southern Fujian, Northern Jiangsu, Northern Anhui, Tianjin, Beijing, and Southwestern Taiwan
IV	1400–2000	4190–5016	140–170	Hunan, Hubei, Guangxi, Jiangxi, Zhejiang, Northern Fujian, Northern Guangdong, Southern Shaanxi, Southern Anhui, Heilongjiang, and Northeastern Taiwan
V	1000–1400	3344–4190	115–140	Sichuan, Guizhou, and Chongqing

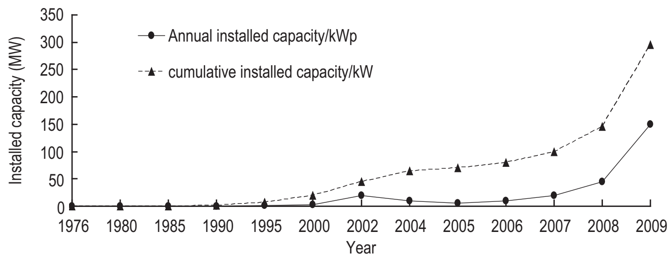


Fig. 1. Installed capacity of the solar PV power in China (1990–2009).

Table 2
Electricity sales in China from 2004 to 2010.

Year	Sales (10^{13} kW h)	Annual growth rate (%)
2004	17,384	
2005	19,554	12.5
2006	22,825	16.7
2007	26,430	15.8
2008	28,418	7.5
2009	30,586	7.6
2010	35,289	13.3

Table 3
The main large-scale PV power generation projects in China (2008–2012).

Project Name	Year	Province	Total installed capacity (MW)
Huancuishan PV power station	2012	Shanxi	30
Xigaze PV power station	2012	Tibet	30
Taiyangshan PV power station	2012	Ningxia	50
Qinghe PV power station	2012	Xinjiang	20
Wuwei PV power station	2012	Gansu	90
Yingjisha PV power station	2011	Xinjiang	20
Wulan PV power station	2011	Qinghai	20
Shizuishan PV power station	2010	Ningxia	50
Xiaowutai, Youyu PV power station Stage I	2009	Shanxi	10
Dunhuang PV power project	2009	Gansu	10
Delingha PV power station	2009	Qinghai	10
Ge'ermu desert PV power station	2009	Qinghai	200
Caidam PV power station Stage I	2009	Qinghai	30
Shilin PV power demonstration station	2008	Yunnan	66

PV power installations will reach 1.8 GWp by 2020 and 1000 GWp by 2050 nationwide in China [10].

To encourage the development of renewable energy such as solar PV power, China has promulgated a series of laws, regulations and financial incentive policies, and has invested significant funds in PV power generation projects. The result of this investment is that China has a number of the world's leading PV companies as well as the successful establishment of research and development centers [11].

Another factor that will increase the market for the solar PV power industry is China's demand for electricity, which continues to grow rapidly. The consumption of electricity in China from 2004 to 2010 is shown in Table 2 [12]. According to the statistics, the electricity sales value in China in 2010 is twice as much as that in 2004, and the average annual growth rate from 2004 to 2010 was more than 12%. This increasing demand for electricity, in addition to the shortage of fossil fuels and the negative impact of environmental pollution caused by the burning of fossil fuels, and the demand for renewable energy will increase which will create opportunities for the solar PV power industry.

In recent years, China has actively supported the development of PV power, and has constructed a series of PV power generation projects, mainly in China's western and northern provinces. Table 3 lists the main large-scale PV power generation projects in China from 2008 to 2012. The installed capacities of these projects are in the range of 5–200 MW. However, most of these projects are located in developing regions (such as Qinghai, Gansu, and Ningxia) where the grid structure is relatively weak and the distance to the load centers is significant. This poses a challenge to use the generated solar power fully and efficiently.

3. The growth route of PV power industry in China

3.1. The main factors affecting solar PV power industry development

The solar PV power supply chain consists of silicon materials, wafers, cells, components, and applications industries that utilize the power created by the solar PV power. The solar PV power industry has a close link with the raw material producers, power generating plants, and power supply companies. China's solar PV power industry chain and its influencing factors are shown in Fig. 2.

In China, the main factors that affect the PV power industry are the technology, the industry plan, the laws, the price and the incentive policies [2,3,8,12]. Technology is a key factor that affects

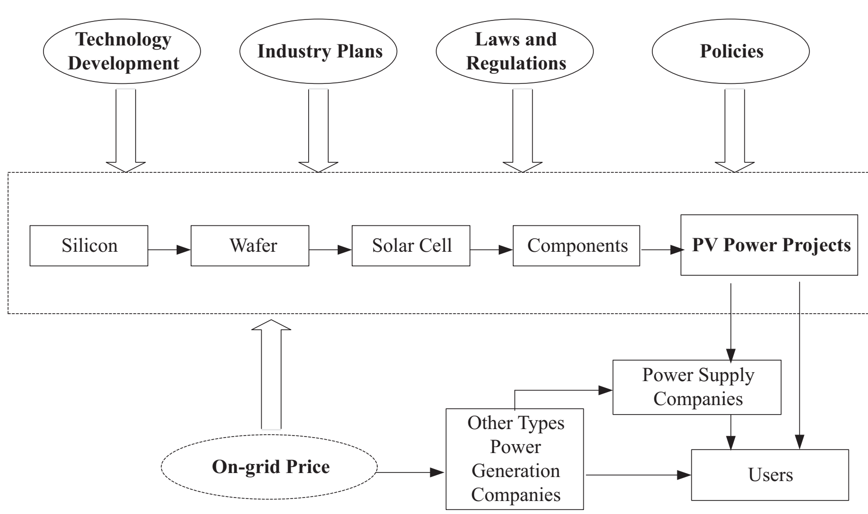


Fig. 2. Diagram of the solar PV power generation industry.

the competitiveness of the PV power industry, especially the cost of solar PV power generation [6]. The government plays a key role by regulating the renewable power market, especially since the current industrial environment is not mature. The Chinese government has formulated a series of industry plans for the PV power development. These industry plans serve as a strategic and directional guide to the development of PV power industry [12,13]. In order to encourage the solar photovoltaic power, China also released supporting laws, policies and regulations. These laws, policies and regulations have an important impact and ensure a framework to sustain the stable, healthy and orderly operation of the PV power industry [4,8]. Related policies, such as electricity price policies, tariff subsidy policies and project incentive policies, provide various advantages and favorable conditions that greatly improve the competitiveness of the industry [4,12]. Therefore, this paper will review and examine the factors affecting the growth of the solar photovoltaic power industry in China based on the following five aspects: (1) the technology development, (2) the industry development plans, (3) the laws and regulations, (4) the electricity price policies, and (5) the project incentive policies.

3.2. The growth route of solar PV power technology development

Since the successful development of the first crystalline silicon PV cell in 1958, China's PV power has evolved, going from small to large in scale, from single arrays to multiple arrays in type, from low to high in conversion efficiency. Milestone events in the development of China's solar energy technology, and in the growth, research and development of the solar PV power technology are shown in Fig. 3.

In China, the technology development of solar PV power can be divided into three stages, germination stage, seedling stage and growth stage.

In the germination stage (from 1958 to 1970s), the development and manufacture of the solar cells was the key goal. In 1968, an institute in Tianjin developed and manufactured the first solar cells in China using satellite technologies. In the 1970s, a few solar cell factories were set up in the cities of Shanghai, Ningbo and Kaifeng.

In the seedling stage (from 1980s to 1990s), the State Scientific and Technological Commission set up China Optics and Electronics Technology Centre, which started the study of monocrystalline silicon solar cells, polysilicon silicon solar cells and the application of PV systems. In 1986, China's first 0.56 kW wind and solar hybrid system was established in Inner Mongolia. In 1989, China's first 10 kW PV power station began operation in Tibet. In the 1990s, the Institute of Electrical Engineering at the Chinese Academy of Sciences developed and constructed an independent PV station. A few production bases were formed in the Pearl River Delta areas and China began to export various PV products.

In the growth stage (from 2000 to present), the Suntech Company and Yingli Green Energy Company constructed the 10 MWp solar cells production lines in 2002 and 2003, respectively. During the last few years, the output of China's solar cells increased rapidly and accounted for 30% of the world's production in 2005. Advances have also been made in research and development. In 2007, the Shanghai Institute of Technical Physics of the Chinese Academy of Sciences invented and developed the physical purification method with which the purity of the solar cell silicon can reach 99.9999%. In 2010, the Shanghai Branch of the Chinese Academy of Sciences successfully developed a method of using physical process technology to produce solar cell grade polysilicon. While there have been numerous advances, China still strives to narrow the gap and make advances in selected aspects of solar power technology, including cell efficiency, components efficiency, production equipment technology and testing technology.

3.3. The growth route of the solar PV power industry development plan

In recent years, China's government issued a series of renewable energy development plans, including the "Renewable Energy Mid and Long-term Plan", "Renewable Energy Development Eleventh Five-Year Plan" and the "Economic and Social Development Twelfth

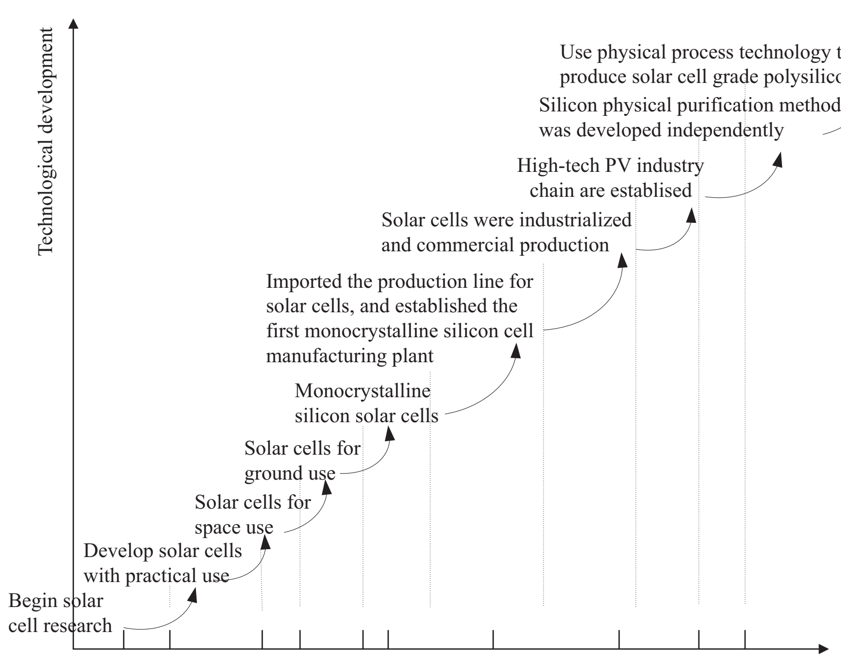


Fig. 3. Milestones in the development of the solar PV power technology development in China.

Five-Year Plan". These plans have a significant impact on the potential growth of the solar PV industry. Milestones in the development of solar power and how these milestones related to the national plans are shown in Fig. 4.

In November 2007, the National Development and Reform Commission (NDRC) issued the "Renewable Energy Middle and Long-term Plan" which identifies the long-term goal of solar power. In the plan, China's annual use of renewable energy will reach the equivalent of 2.7 hundred million tons of standard coal by 2010, with solar power contributing 300 MW to this goal. By 2020, the portion of China's energy use, that will be served by renewable energy, will increase to 16% (compared to 7% in 2007) and the amount of energy provided by solar power will reach to 1800 MW [13].

One year later, in March 2008, according to the requirements of the "Renewable Energy Mid and Long-term Plan" and the new development of renewable energy in China, the NDRC issued a "Renewable Energy Development Eleventh Five-Year Plan". This plan proposed to establish national standards for public lighting in urban areas using PV, and technical standards to support PV construction, including the addition of building on-grid PV, large-scale on-grid PV and other technical standards [14]. This plan identified the construction of the rooftop PV generating system in city housing and large-scale on-grid PV power plant as key projects for solar energy utilization and development. The plan also outlined a development plan and technological categories for solar power in different regions.

In line with the rapid development of China's solar energy industry and the huge market potential, the State Council published the "Economic and Social Development Twelfth Five-Year Plan" in March 2011. This plan clearly stated that the country will:

- promote renewable energy production,
- build a safe, stable, economical and clean modern energy industrial system,
- accelerate the development of new energy projects, and
- use the traditional energy by more clean and efficient ways [15].

This plan also proposed that the Chinese government support and fund the research and development of the key technologies for new energy and energy conservation.

Similarly, some provincial governments also released supporting policies to promote the solar PV power development. For instance, the Jiangsu provincial government issued implementing notices on solar PV industry in 2009. This policy stipulated that the government will develop the solar power industry through supporting policies, the development of relevant standards and the provision of incentives [16]. Other provinces such as Hebei, Shanghai, Zhejiang, Shandong, and Fujian, are taking a similar approach. The goal for the development of solar PV power generation is shifting from an emphasis on the growth rate of installed capacity to a long-term program with orderly progress of the industry.

3.4. The growth route of the laws related to the solar PV power

To encourage and promote the development of the solar energy industry, China has promulgated a series of supporting laws and regulations in recent years. Fig. 5 illustrates the development of the laws related to the solar PV power generation. These laws created a framework of regulations and rules to protect the PV power industry.

The Renewable Energy Law was approved by the Tenth National People's Congress on February 28, 2005. This law requires the central government and each provincial government to identify medium and long-term goals for the use of renewable energy. The government encourages and supports renewable

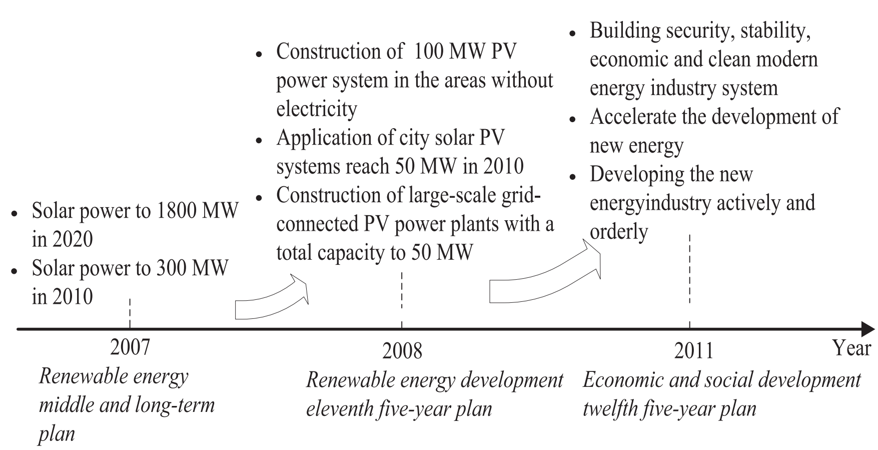


Fig. 4. Milestones in the growth of solar PV power industry programs in China.

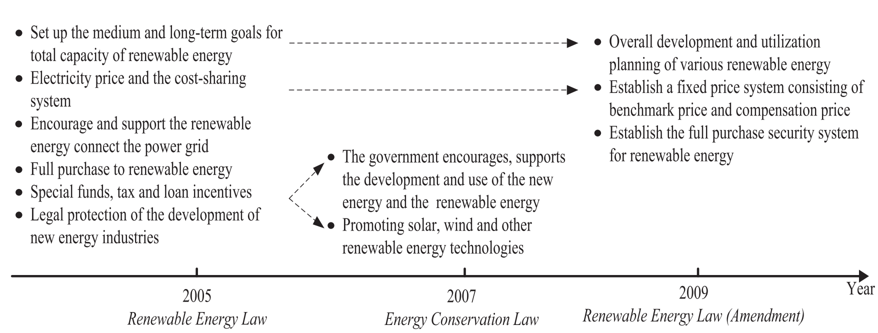


Fig. 5. Legislative milestones in support of solar PV power in China.

energy by regulating connections to the state power grid. The grid corporations must purchase all the electricity that is generated from renewable energy sources within the area served by their power grid [17]. The law also promised to provide special funds, tax deduction and favorable loans as incentives for the development of renewable energy. According to the law, if the cost of renewable energy is higher than that of traditional energy sources, the gap shall be shared among the end users across the nation.

Although the full purchase of renewable energy had been regulated by the Renewable Energy Law, a conflict of interest existed between the power generation company and the grid company because the grid company was unwilling to purchase the electricity generated from renewable sources with a high price. As a result, the policy requiring the full purchase of renewable energy was difficult to implement fully. To solve this problem, in 2009, the Renewable Energy Law was amended and regulated the full purchase security system. According to the amended law, the NDRC together with the State Electricity Regulatory Commission and the Ministry of Finance shall determine the required ratio of renewable energy power to the total power generation capacity. This ratio shall be determined periodically according to the national medium and long-term plan, and shall formulate the implementation method for the grid companies, with priority to purchase the renewable energy power [18]. This law also established a renewable energy development fund based on the experiences of the developed countries.

Furthermore, the Energy Conservation Law promulgated on October 28, 2007 explicitly stated that China recognizes saving resources as a basic long-term national strategy, and conservation and development are equally important with conservation as a top priority in the energy development strategy [19]. The law clearly states that China encourages and supports the development and use of new energy, renewable energy and the biomass in rural areas, and China will widely promote the biomass, solar and wind and other renewable energy technologies.

3.5. *The growth route of solar PV pricing policy*

As a kind of renewable energy, solar PV power competes with and complements traditional energy and other kinds of renewable energy. In China, although the on-grid price of solar PV has gradually declined, still it is highly relative to traditional energy and relative to other kinds of renewable energy [20]. As shown in Table 4, this price differences have greatly weakened the competitiveness of solar PV power generation and restricted the development of large-scale PV power generation.

The cost of solar cells constitutes the largest share of the total cost of PV power generation. Solar cells include crystalline silicon solar cells and amorphous silicon solar cells. The former includes monocrystalline silicon solar cells and polycrystal silicon solar cells. The development of monocrystalline silicon cells is still in the early stages, but the production cost is high due to the use of high-purity silicon, and the raw materials cost accounts for more than half of the total cost. Compared with the monocrystalline silicon cells, the cost of the polycrystal silicon cell is low because the production process is relatively simple. In recent years, the amorphous silicon solar cell has been mass produced for use as a low-cost solar cell.

The evolution of the cost of solar cell power during the last 30 years in China is shown in Fig. 6. In the 1970s, the solar cell power cost was as high as 200 Yuan/kW h. In the 1980s, China's PV industry made progress and the cost of solar cell power reduced to 40–45 Yuan/kW h. By the end of 2000, China's amorphous silicon solar cell power cost was 23–25 Yuan/kW h. In 2008, the cost of solar cells in China was 10–75 Yuan/kW h. In 2010, China's solar PV cells power cost is down to approximately 1 Yuan/kW h [21].

To support the solar PV power industry, the government has promulgated a series of policies to supply on-grid solar PV power. The growth of the financial subsidy policies related to the solar PV power pricing is shown in Fig.7.

The NDRC released the "Trial Measures on Renewable Energy Prices and Cost-sharing Management" in January 2006; this regulated the renewable energy prices and implemented the government pricing and government guiding prices. Solar power projects and prices for on-grid solar power are regulated by government pricing, with the standard price determined by the Bureau of Commodity Prices of the NDRC. In this framework, the price is based on the actual cost plus a reasonable profit. At present, the subsidy for solar power is 0.25 Yuan/kW h. The government encourages the users to buy renewable energy power [22]. The Ministry of Finance promulgated the "Procedures for the Administration of Special Funds for Renewable Energy Development" in May 2006. This policy administers special funds that support the promotion and application of wind power, solar power, and ocean power, and also support the application of solar energy and geothermal energy for building energy conservation [23].

In January 2007, the NDRC issued the "Interim Measures on Renewable Energy Subsidy Management" to ensure rational use and distribution of the subsidy of renewable energy. It is stipulated that the range and standard rates of subsidy to solar PV shall be approved and announced by the Bureau of Commodity Prices of the NDRC [24]. The subsidies for solar PV power generation projects include: (1) the excess of the on-grid price of renewable energy power over the standard on-grid price of the local desulfurized coal-fired units; (2) the excess of the operation and maintenance costs of the independent solar PV power systems by public investment over the local grid average sale price; and (3) the grid connections costs of the solar power projects.

The Ministry of Finance of China issued the "Interim Measures on Management of Financial Fund for Solar Building" in March 2009, which regulates the subsidy standard for solar buildings

Table 4
The on-grid prices of various power generation types in China (2010–present).

Type	On-grid power price (Yuan/kWh)	Equivalent to US cents (1 US$ ≈ 6.3 China Yuan)
Hydropower	0.265	4.21
Coal-fired power	0.35	5.56
Nuclear power	0.44	6.98
Liquefied natural gas	0.53	8.41
Wind power	0.56	8.89
Biomass power	0.75	11.90
PV power	1.00–1.50	15.87–23.81

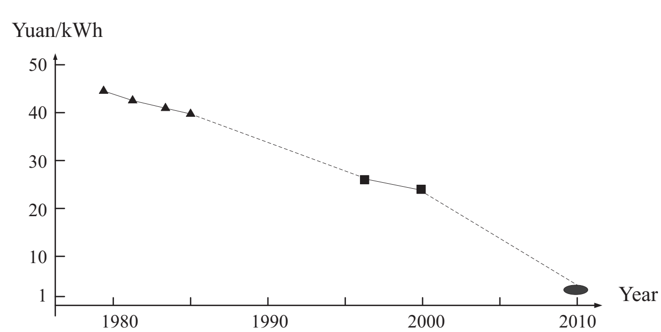


Fig. 6. Evolution route of the solar cells power cost in China.

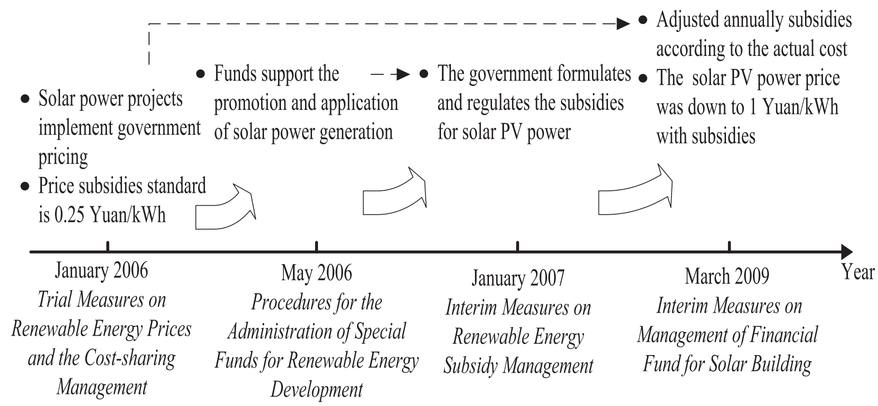


Fig. 7. Growth of financial subsidy policies supporting solar PV power pricing in China.

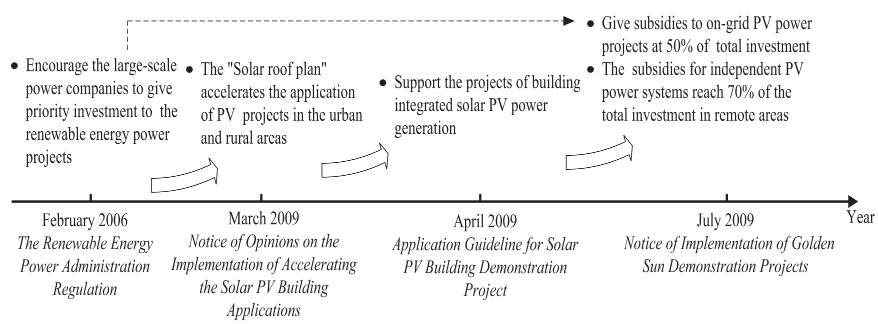


Fig. 8. Growth route of the incentive policies to the solar PV power projects in China.

that will be adjusted annually according to the actual cost [25]. This policy gives full support to the solar energy and the building integration applications, and as a result the solar power cost will reduce to 1 Yuan/kW h through use of the subsidies.

In China, the PV power prices are not the same in all regions. Different regions and different projects have different PV power prices due to the different approved prices by the government. However, with the reduction in the cost and the subsidy support by various policies, the PV power price continued to decline. The PV power prices continue to become closer to traditional power prices steadily.

3.6. The growth route of the incentive policies to the solar PV power projects

PV power generation includes independent PV power system (off-grid) and grid-connected PV power system (on-grid). In the 20th century, due to the high cost of PV cells, PV power generation is mainly used in island, mountain, desert and other remote areas where the public power grid cannot reached. In recent years, the PV power, including power generation and PV construction, have been gradually extended to include both on-grid and off-grid power systems in cities and rural areas. In 2002, China launched the "Electricity Plan for Remote Villages in Western Provinces", by establishing PV power and other power generation projects to provide electricity for poor and remote villages. In 2009, the government issued a series of project policies such as the "Golden Sun Demostration Projects" and the "Solar Roofs Plan" to support solar power development, and China was ranked in the top ten of PV markets throughout the world. In the next 10 years, China's solar PV power market will turn from independent power systems to grid-connected power systems, which will include desert power stations and city roof power systems. The growth route of the policies to the solar PV power projects are shown in Fig.8.

In February 2006, the NDRC published "The Renewable Energy Power Administration Regulation" to stipulate the requirements for the power generation companies engaged in the solar PV power generation business. And power generation enterprises are encouraged to increase their investment in the renewable energy projects [26]. Solar PV power projects are under the policies of the NDRC and can receive financial support from the NDRC. According to the regulation, the power grid companies shall invest in solar power and undertake to connect the solar power generation plants into the public grid system.

In March 2009, the Ministry of Finance and the Ministry of Housing and Urban–Rural Development issued the "Notice of Opinions on the Implementation of Accelerating the Solar PV Building Applications" to implement the "Solar Roofs Plan" which adopted a demonstration project to speed up the implementation of PV projects in urban and rural areas [27].

In April 2009, the Ministry of Finance and the Ministry of Housing and Urban–Rural Development published the "Application Guideline for Solar PV Building Demonstration Project". The guideline supports the solar PV building projects [28]. The government will provide subsidies for solar PV building application demonstration projects, and the maximum subsidy is 20 Yuan/W.

In July 2009, the Ministry of Finance, the Ministry of Science and Technology, and the National Energy Board jointly issued the "Notice of Implementation of Golden Sun Demonstration Projects" which regulated that the government will provide subsidies to on-grid PV power projects at 50% of the total investment, and the subsidies for independent PV power systems will reach 70% of the total investment in remote areas without electricity [29].

This policy illustrates the strong support that the Chinese government provides to encourage the investment and operation of solar PV power projects. This policy also launched a series of incentives for PV power generation projects. The policies are

gradually shifting from encouraging the large companies to invest in PV power generation projects to implemente subsidies for PV projects. The subsidies for PV power generation projects have reached as much as half of the total investment for a project. In addition, the policies for the PV projects have expanded from supporting solar PV power plant projects to encouraging the construction of solar buildings.

4. Conclusions

China has abundant solar energy resources. As a result, the solar photovoltaic power industry has undergone significant growth in the last decade and has great potential in the future. This study analyzes the changes in China's solar PV power industry growth, including research and development of technology, industrial plans, laws and regulations, electricity price policies, and projects incentive policies.

Currently, China's PV power industry is in a stage of vigorous development, and the research and development supporting PV power technology is rapidly progressing. Since 2000, China's PV power technology development has improved dramatically, with technological advances in the efficiency, the reliability, and reduced pollution of PV cells and PV power generation systems. Advances in technology have reduced the cost of PV cells and power generation systems, and the application of PV technology has been expanded. However, China has still lagged behind the advanced countries in cell and components efficiency, production equipment technology and testing technology. These aspects are the focus of research and development in China. The Chinese government has formulated and implemented a series of medium and long-term development plans to support the progress of the solar PV power industry. The planning objectives are gradually changing from targets for installed capacity to the development of a clean industry. The promulgation of the "Renewable Energy Law" and its amendments played a significant role in the promotion of the PV power industry, such as the full purchase requirements for solar power and other renewable energies. The "Energy Conservation Law" strengthens the legal responsibilities for energy conservation and gives priority to green energy sources such as solar power. At present, one of the main challenges of the solar PV power industry is the high cost. The Chinese government is supporting and promoting PV power projects through tax deductions as well as subsidies. These incentives have reduced the PV power price and promoted the sustainable development of the PV power industry. Furthermore, China's PV power projects are becoming increasing large-scale and on-grid, as the supporting policies are issued and put into practice. The scope and content of the subsidies are continuously adjusting to adapt the development of the PV power industry.

The political and economic environment in China is suitable for the development and growth of the solar PV power industry. In the future, the formulation of PV power industry development plan will increase considering the sustainability and capacity building rather than the government subsidies. The future competitiveness of China's PV power industry will mainly rely on cost reductions, increased power efficiency and improved reliability. In the future, the development and expansion of the industry will rely on technical progress rather than dependence on preferential government policies. This is true for renewable energy in countries around the world and China will have same lessons in other markets.

However, the factors that affect the PV power industry are various and complicated. The limitation of this study is that it addressed only five main factors as a framework to explore the emergence and development of solar power in China. Further research opportunities exist to find more factors to study the growth routes and trends of the solar power industry. In a dynamic technology, social and market environment, these factors are changing continually. Therefore, there will be on-going opportunities to explore the dynamic process and growth of the industry.

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